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Decomposition Analysis of Technological Change in Rice Production in Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author ET designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed literature searches. Authors KOY, SCF and ITA managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The study was conducted in Ejura-Sekyedumase Municipality of the Ashanti Region and the Atebubu-Amantin Municipality in the Brong-Ahafo Region of Ghana, in May 2013, to investigate the technological change in rice production in the two municipalities in Ghana using the output decomposition analysis approach. The study adopted a descriptive research design, based on a cross-sectional survey strategy. The study involved 216 sampled smallholder rice farmers (107 adopters of the improved variety and 109 non-adopters) using a three-stage stratified random sampling method involving operational areas, communities, and farmers. Data were collected by trained agricultural extension agents and monitored by the researchers. The Cobb-Douglas production and a modified decomposition analyses techniques were used to decompose the sources of productivity differences between the improved rice variety and the unimproved rice variety. Out of 216 rice farmers sampled, 208 completed their questionnaires. The study found that

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seed, fertiliser, and herbicide had a significant influence on the yield of the improved and unimproved rice varieties. Further, the ratios of the marginal value product to marginal factor costs were equal to unity for all the inputs, except labour; an indication that the resources were underutilised. The decomposition analysis showed that the estimated productivity differences between the improved and unimproved rice varieties were 39.46 percent. Productivity differences between the improved and unimproved rice varieties were mainly due to non-neutral technical change, which accounted for 44.65 percent. The study concludes that technological change in rice production in the two municipalities was mainly of the non-neutral type. Designing appropriate extension strategies and capacity building for the rice farmers could lead to improvement in their productivity.

Keywords: Rice; decomposition analysis; technical change; productivity differences.

1. INTRODUCTION

Advancement in the development of technological innovations in rice cultivation is crucial for enhancing productivity and sustaining food security in Ghana. Globally, rice (*Oryza sativa*) is the most significant staple food for most of the human populace [1]. In Ghana, it has become the second most important food staple after maize and its consumption keeps increasing because of population growth, urbanisation, and change in consumer behaviours [2]. Consequently, Ghana spends about US $600 million annually on import as total rice consumption is estimated at 500,000t [3]. The country's food balance sheet for 2010/2011 presents an alarming picture, giving the reported net deficit of -41,835 Mt of milled rice [4]. Policy reforms are, therefore, required to either use revenues from the import of products such as cocoa to finance the import of rice or promote local rice production through increased investment in rice productivity-enhancing technologies.

Successive governments since independence have continued to invest in the development, dissemination, and promotion of improved agricultural technologies. Smallholder farmers benefit from technological change either by increasing output from the same inputs or by holding the same output from reduced inputs [5, 6]. A major technological breakthrough in the production of rice is the development of the New Rice for Africa (NERICA) by the African Rice Centre. NERICA is one of the main high yielding technological advances in the agricultural sector. The improved rice variety is produced through conventional crossbreeding between an ancient, hardy African rice variety (*O. glaberrima* Steud), and a high-yielding Asian variety (*O. sativa* L.) [7]. There are more than 3000 lines in the family of NERICA [8]. The major advantages of the improved rice variety are its higher yielding advantage, as well as resistance to drought, diseases, and pests. The potential yield of NERICA depends on the particular NERICA lines; higher yields up to 6t ha^{-1} are obtained when appropriate levels of fertiliser are used [9,7]. Moreover, NERICA is early maturing (within 80 – 100 days, i.e., 50 – 70 days earlier than farmers' varieties) and is resistant to local stresses such as blast, stem borers, and termites [7]. It, therefore, has the additional advantage of being climate-smart.

Research shows that in a rain-fed dependent upland production system, NERICA farmers reported high yields between 3 and 6t ha^{-1} [10]. This is against the very low yields of between 0.7 and 1.5 t ha^{-1} [11] of normal rice varieties grown under the same system. Similar studies conducted in West African countries revealed significant positive impacts with an additional yield gain of nearly 1t ha^{-1} in Benin [12] and 140 kg ha^{-1} in The Gambia [13]. Also, prior studies suggest that improved rice varieties have increased the costs and returns and thus the profitability of farmers who have embraced them [14]. Therefore, the technological breakthrough in rice production has obviously generated increased productivity and profitability for the rice farmers. However, the questions that arise are what are the nature and exact magnitude of the technological breakthrough associated with the improved rice variety and what policy alternatives exist for converting its potentials on a sustained basis for the socio-economic development of farmers?

Existing research on the improved rice variety [13,10] neglect to consider the nature (i.e., whether technological change is neutral or non-neutral) and magnitude of the change in the technology of rice production from the unimproved to improved rice varieties. More clearly, prior research suggests that technical change and input use differentials might be key factors in driving the productivity differences between unimproved and improved crop varieties [15,16]. However, no systematic analysis of how these factors explain the productivity differences between the improved and unimproved varieties was carried out. Moreover, existing research in Ghana has failed to address these two key issues on the technological change associated with the improved rice variety. This study has the potential to provide a better theoretical and practical understanding of the nature and magnitude of the technological change associated with the improved rice variety. This study further decomposes the sources of productivity differences between the adopters and non-adopters of the improved rice variety.

2. METHODOLOGY

2.1 Study Area and Sampling Technique

The study was conducted in the Ejura-Sekyedumase Municipality of the Ashanti Region and the Atebubu-Amantin Municipality in the Brong-Ahafo Region of Ghana. The data used in this study were from the 2012 survey of rice farmers in the two municipalities. This study was based on the input-output data obtained from the rice farmers in the two municipalities selected using multi-stage stratified random sampling method. The choice of this method was due to its ability to ensure a high degree of representativeness by providing the elements with equal chances of being selected [17]. The first stage involved a simple random sampling of three operational areas from each of the two municipalities. The selection was based on the dominance of the adopters and non-adopters of the improved rice variety. For each operational area, two rice growing communities were selected (totalling 12 communities), using simple random sampling based on the same criteria. The final stage involved the selection of 18 rice farmers from each of the selected communities using stratified random sampling technique. The rice farmers were divided into two strata, namely, adopters and non-adopters. Nine farmers from each stratum were then selected using simple random sampling. Thus, 216 rice farmers in the two municipalities were sampled for the study. Out of these, 208 were considered sufficiently complete to be usable. This comprised 105 adopters and 103 non-adopters of the improved rice variety. Data were collected by the researchers with support from five agricultural extension agents.

2.2 Empirical Specifications

2.2.1 Decomposition analysis

The output decomposition model developed by Bisaliah [18] was used to estimate the output productivity differences between the unimproved and the improved rice varieties. It was further used to identify the contribution of technology and resource use differentials to the productivity differences. The decomposition analysis presents a modification of Bisaliah's [18] approach, based on the Cobb-Douglas production (CDP) model. Several studies have used this approach extensively [15,16,19]. Therefore, it was considered appropriate for this study. The model specification used in this study was based on three assumptions: (a) all relevant inputs are observed; implying no effect of factors such as management capabilities or soil quality or water access; (b) adoption was assigned randomly and not, for example, that better farmers were more likely to adopt; and (c) the quantity of seeds is the same input for adopters and non-adopters, but the essence of the new variety is incorporated in the seeds. Accordingly, the production function for the improved rice variety or adopters (A) is expressed as:

$$Y_A = \alpha_A S_A^{B_1} L_A^{B_2} F_A^{B_3} H_A^{B_4} u_A \tag{1}$$

Similarly, the production function for the unimproved rice variety or non-adopters (NA) is given as:

$$Y_{NA} = \alpha_{NA} S_{NA}^{Z_1} L_{NA}^{Z_2} F_{NA}^{Z_3} H_{NA}^{Z_4} u_{NA} \tag{2}$$

These two production functions [equations (1) and (2)] were transformed into the logarithmic form. The specifications are as follows:

$$InY_A = In\alpha_A + B_1 InS_A + B_2 InL_A + B_3 InF_A + B_4 InH_A + u_A \tag{3}$$

$$InY_{NA} = In\alpha_{NA} + Z_1 InS_{NA} + Z_2 InL_{NA} + Z_3 InF_{NA} + Z_4 InH_{NA} + u_{NA} \tag{4}$$

Where: Y = yield of paddy (kg ha^{-1}); α = scale parameter; S = quantity of rice seeds (kg ha^{-1}); L = number of labour used (person-days ha^{-1}); F = quantity of fertiliser (kg ha^{-1}); H = quantity of herbicide (*l* ha^{-1}); B_i = output elasticity of inputs for the adopters; Z_i = output elasticities of inputs for the non-adopters, and U_i = disturbance terms. Taking differences between equations (3) and (4) give:

$$\begin{aligned} InY_A - InY_{NA} = {} & (In\alpha_A - In\alpha_{NA}) + (B_1 InS_A - Z_1 InS_{NA}) + (B_2 InL_A - Z_2 InL_{NA}) \\ & + (B_3 InF_A - Z_3 InF_{NA}) + (B_4 InH_A - Z_4 InH_{NA}) + (u_A - u_{NA}) \end{aligned} \quad (5)$$

Adding and subtracting $\sum_{i=1}^{4}[\beta_i InX_{NAi}]$ in equation (5) and rearranging gives:

$$\begin{aligned} [InY_A - InY_{NA}] = {} & [In\alpha_A - In\alpha_{NA}] + [(B_1 - Z_1)InS_{NA} + (B_2 - Z_2)InL_{NA} \\ & + (B_3 - Z_3)InF_{NA} + (B_4 - Z_4)InH_{NA}] + [B_1(InS_A - InS_{NA}) \\ & + B_2(InL_A - InL_{NA}) + B_3(InF_A - InF_{NA}) + B_4(InH_A - InH_{NA}) \\ & + [u_A - u_{NA}] \end{aligned} \quad (6)$$

By applying logarithm rule, equation (6) becomes;

$$\begin{aligned} In(Y_A / Y_{NA}) = {} & [In(\alpha_A / \alpha_{NA})] + [(B_1 - Z_1)InS_{NA} + (B_2 - Z_2)InL_{NA} \\ & + (B_3 - Z_3)InF_{NA} + (B_4 - Z_4)InH_{NA}] + [B_1 In(S_A / S_{NA}) \\ & + B_2 In(L_A / L_{NA}) + B_3 In(F_A / F_{NA}) + B_4 In(H_A / H_{NA}) \\ & + [u_A - u_{NA}] \end{aligned} \quad (7)$$

Equation (7) subsequently translates into:

$$In(Y_A / Y_{NA}) = In(\alpha_A / \alpha_{NA}) + \sum_{i=1}^{4}[B_i - Z_i]InX_{NA_i} + \sum_{i=1}^{4} B_i \left[In(X_{A_i} / X_{NA_i} \right] \quad (8)$$

Where;

$In(Y_A / Y_{NA})$ = Per-hectare output differences between adopters and non-adopters. It gives approximately a measure of the percentage change in output with the introduction of the improved rice variety.

$In(\alpha_A / \alpha_{NA})$ = Output differences due to neutral technical change.

$\sum_{i=1}^{4}[B_i - Z_i]InX_{NA_i}$ = Output differences due to non-neutral technical change.

$In(\alpha_A / \alpha_{NA}) + \sum_{i=1}^{4}[B_i - Z_i]InX_{NA_i}$ = Output differences due to technical change.

$\sum_{i=1}^{4} B_i \left[In(X_{A_i} / X_{NA_i} \right]$ = Output differences due to input use differentials, and $[u_A - u_{NA}]$ = Differences in the error term.

Using equation (7), the per-hectare productivity difference between the adopters and non-adopters was decomposed into three components. These are neutral technical change (i.e., a shift in the intercept of the production function); non-neutral technical change (i.e., a shift in the slope parameters of the production); and change in the volume of inputs used (i.e., rice seed, labour, fertiliser, and herbicides).

2.2.2 Test for structural differences and sources

The structural differences in the production functions derived from the adopters and non-adopters were tested using the dummy variable approach [20]. This technique helped to establish whether the difference in the two regressions was because of differences in the intercept terms or the slope coefficients, or both. It also helped to establish the nature of the technical change associated with the improved variety i.e., whether the technical change associated with the improved rice variety was of the neutral or non-neutral type. Accordingly, the intercept and slope dummies were introduced into the log-linear production function as:

$$InY = Ina + b_1 InS_1 + b_2 InL_2 + b_3 InF_3 + b_4 InH_4 + cD + d_1[D_1 InS_1] + d_2[D_2 InL_2] + d_3[D_3 InF_3] + d_4[D_4 InH_4] + u \quad (9)$$

Where: D = Varietal intercept dummy; 1 for adopters and 0 for non-adopters.

$\sum_{i=1}^{4} d_i[D_i InX_i]$ = Slope dummies of seed, labour, fertiliser, and herbicide; taking the values of 1 for the adopters and 0 for non-adopters.

2.2.3 The efficiency of resource use

Resource use efficiency (RUE) among the rice farmers was computed from the estimated production functions shown in equations (3) and (4). The marginal value product (MVP) of a particular resource was computed at the arithmetic mean, all other resources being held constant at the arithmetic means. Mathematically, the MVP is given by:

$$MVP_{X_i} = a_i \frac{M_Y}{M_{X_i}} \quad (10)$$

Where M_Y and M_{X_i} are the arithmetic means of output and of the i^{th} resources or input, as defined above. In addition, a_i is the regression coefficient of inputs obtained from the two equations. The MVP was compared with the marginal factor cost (MFC). The MFC was computed using:

$$MFC_{X_i} = \frac{\Delta X_{TC_i}}{\Delta X_{q_i}} \quad (11)$$

Where ΔX_{TC_i} indicates the change in total costs of the i^{th} resource, and ΔX_{q_i} is the change in the physical quantity of the i^{th} resource. The RUE is expressed as:

$$RUE = \frac{MVP_{X_i}}{MFC_{X_i}} \quad (12)$$

The ratio is a measure of RUE. If RUE > 1, the resource is underutilised (i.e., resource needs to be expanded); if RUE = 1, the resource is efficiently or optimally utilised and if RUE < 1, the resource is over-utilised (i.e., resource needs to be contracted).

3. RESULTS AND DISCUSSION

3.1 Mean and Mean Differences in Input Usage between Non-adopters and Adopters

Table 1 presents the mean and mean differences of the variables used in the CDP function and the decomposition analysis. There is ample evidence of differences in the per hectare use of inputs among the rice farmers. Labour (135.66 person-days ha^{-1}) and fertiliser (319.64 kg ha^{-1}) applications were higher for the adopters than the non-adopters. Non-adopters, on the other hand, reported higher use of seed (71.68 kg ha^{-1}) and herbicide (4.71 *l* ha^{-1}) compared with the adopters. The results indicated that the use of labour and fertiliser, as well as yield, were significantly higher for the adopters compared to the non-adopters. However, non-adopters used significantly higher quantities of seed than the adopters. The higher seeding rate among the non-adopters is partly due to the use of uncertified or poor quality seeds, which require increased replanting because of lower emergence rates. The higher demands for labour and fertiliser among the adopters could be due to the responsiveness of the improved rice variety to such inputs. Notwithstanding, the improved rice variety requires less seed and herbicide because of its high-quality seed and weed-competitive nature. The results are consistent with [7] who reported that the improved rice variety is of high quality and are weed-competitive leading to higher emergence rates. Therefore, the adoption of the improved rice variety could result in substantial yield gain and reduction in the cost of seeds and herbicides.

Table 1. Mean and mean differences in inputs use between non-adopters and adopters

Variables	Mean	Non-adopters	Adopters	Differences	t-statistics	p-value
Yield (kg ha^{-1})	2487.32	1936.89	3027.26	1090.37	7.97	.00**
Seed (kg)	64.78	71.69	58.00	13.69	-5.52	.00**
Labour (person-days ha^{-1})	126.28	116.89	135.66	18.77	2.08	.04*
Fertiliser (kg ha^{-1})	258.71	196.60	319.64	123.04	6.13	.00**
Herbicide (*l* ha^{-1})	4.71	4.71	4.29	0.42	.02	.99
Sample size	208	103	105			

*Note: *p < .05, **p < .01*

3.2 Estimated Per Hectare Production Functions

Table 2 presents the estimates of the per-hectare production function for the adopters and non-adopters in the two municipalities. The explanatory powers of the per-hectare production functions for the non-adopters and adopters were low (i.e., 0.36 and 0.20, respectively), suggesting that although highly significant at the 1% level, the models generally fit the data moderately. This implies that the variations in the (log of) the per-hectare productivities were explained by 36% and 20% of the (logs) of all the explanatory variables for the non-adopters and adopters, respectively. The output elasticities satisfied a priori expectations. Gujarati [20] justifies the possibility of low R^2 in cross-sectional data due to the diversity of its units. Gujarati [20] further recommends that the relevancy of a model should be judged in the light of the correct specification, correct expected signs of the regressors, and statistical significance of the regression coefficient. Accordingly, these conditions have been satisfied in this study.

For the non-adopters, the seed, fertiliser, and herbicide were statistically significant at the 5% and 1% probability levels, respectively. The output elasticities of these variables are consistent with the expected signs and economic logic. The output elasticities of seed, fertiliser, and herbicide were 0.24, 0.08, and 0.24, respectively. In other words, holding other factors constant, a 1% increase in seeding rate is associated with an average of 0.24% increase in the yield of the unimproved rice varieties. Similarly, on the average, a 1% increase in the quantity of herbicide leads to 0.24% increase in the yield of the unimproved rice varieties, holding all other factors constant. In addition, holding all other factors constant, a 1% increase in the use of fertiliser leads, on the average, to 0.08% increase in production. Overall, the use of seed, herbicide, and fertiliser were the major determinants of the yield of the unimproved rice varieties in the two municipalities. The low impact of fertiliser on the yield of the unimproved rice variety could be due to the lack/delay/inadequacy of fertiliser application among the non-adopters. These results are consistent with the studies by [14] and [19] who found seed, herbicide, and fertiliser to have significant effects on the yield of unimproved rice varieties.

Table 2. Per-hectare CDP estimates for the non-adopters and adopters

Variables	Non-adopters	Adopters
Intercept	5.89** (.53)	5.95** (.91)
Seed	.24* (.10)	.50** (.19)
Labour	-.04 (.05)	-.09 (.08)
Fertiliser	.08** (.02)	0.07** (.02)
Herbicide	.24** (.24)	.01 (.59)
No. observations	103	105
R^2	.36	.20
F-value	13.78**	6.15**
JB test	1.06	1.26

*Note: *p < .05, **p < .01; JB: Jarque-Bera test of normality. Figures in parentheses are standard errors*

The output elasticities for the adopters indicated that the significant variables were seed and fertiliser. Besides, all the significant variables had their expected signs. Seed and fertiliser had output elasticities of 0.50 and 0.07, respectively. The results indicated that a 1% increase in the seeding rate, when all other factors are constant, leads to an average increase of 0.50% in the yield of the improved rice variety. The output elasticity of fertiliser suggests that, if all other factors remain constant, a 1% increase in the quantity of fertiliser application leads to an average increase yield of 0.10% of the improved rice variety. The high elasticity of seed rate underlines the importance of the improved seed in the production of rice. Therefore, seed rate is the most important factor in the production of the improved rice variety. The low effect of fertiliser on the yield of the improved variety is due to the use of fertiliser below the recommended level. For instance, even though the Ministry of Food and Agriculture recommended 375 kg ha^{-1} of fertiliser for the improved rice variety [9], most of the adopters, on the average, applied 319.64 kg ha^{-1} of fertiliser to the improved rice variety.

Generally, the output elasticity of seed is higher for the adopters compared to the non-adopters. In contrast, non-adopters reported higher output elasticities for fertiliser and herbicide. The results also indicated that the intercept term for the adopters (i.e., 5.95) was slightly higher, compared with the non-adopters (5.89). This virtually signifies a slight upward shift in the production function due to technological change associated with the improved rice variety. The sum of the output elasticities for the variable inputs gives 0.52 and 0.49 for the non-adopters and adopters, respectively. This suggests that the rice farmers during the 2012 production season experienced diminishing returns to scale. However, there is no evidence to suggest that these values (i.e., 0.52 and 0.49) are statistically different from one. Hence, a linear equality restriction was tested for the per-hectare production functions by imposing the restriction that there are constant returns to scale. The null hypothesis was that the sum of the output elasticities of the per-hectare production functions equals to one. The F-test for the non-adopters reported $F(1, 98) = 11.11$, with p-value = 0.01 while that of the adopters reported $F(1, 100) = 5.35$, with p-value = 0.02. The F values for the non-adopters and adopters were significant at the 5% level. Therefore, the researchers reject the hypothesis of constant returns to scale in the per-hectare production functions for the non-adopters and adopters. The findings suggest that the production of the unimproved rice varieties and the improved rice variety were characterised by diminishing returns to scale during the 2012 production seasons in the two municipalities. In other words, a one percent increase in all inputs leads to less than same percentage increase in output, all other factors held constant. Thus, the choice of the CDP model was appropriate for the data.

3.3 Tests for Structural Differences between the Non-adopters and Adopters

Sources of structural differences in the coefficients of the per-hectare production function for the adopters and non-adopters were tested using the dummy variable technique. The test was also used to establish whether the shift from the unimproved to the improved rice variety was of the neutral or non-neutral type. The results of the structural difference test are presented in Table 3. The differential intercept coefficient (i.e., the coefficient for the intercept dummy variable) was statistically insignificant. Hence, the hypothesis that the regressors for the adopters and non-adopters have the same intercept was not rejected. The differential slope coefficients (i.e., the coefficient for the slope dummies for seed, labour, and fertiliser) were all statistically insignificant, except for herbicide. Hence, the hypothesis that the two regressions have different slopes was rejected. This implies that structural differences in the regressions for the adopters and non-adopters are due to the differences in the use of herbicide. Overall, the analysis of covariance gives an F-ratio of 15.46 with 5 and 198 degrees of freedom, which is significant at the 1% level. We thus reject the null hypothesis of no structural difference in the two regressions. The results illustrate that the main source of structural difference in the two regressions is the shift in the slope parameter and the shift in the herbicide parameter, in particular. The nature of the impact of the improved rice variety on the per-hectare productivity of rice was, therefore, due to the non-neutral technical change rather than neutral technical change. That is, the shift from the unimproved rice varieties to the improved rice variety was biased towards the use of herbicide.

3.4 Resource Use Efficiency in Rice Production

The marginal value products (MVP) of the resources were compared with the respective marginal factor costs (MFC) to determine the resource use efficiency (RUE) in rice production. This provides the scope for the intensification of resources by the adopters and non-adopters. The MVP and MFC ratios for the various resources for the adopters and non-adopters are presented in Table 4. It can be seen that the ratios of MVP to MFC for both the adopters and non-adopters were greater than unity for all the inputs, except labour. This implies that both the adopters and non-adopters underutilised seeds, herbicides, and fertilisers. Therefore, there is evidence that rice farmers in the two municipalities can probably generate higher output and thus profit in the long-run by using more seeds, herbicides, and fertiliser. In contrast, the negative ratio of MVP to MFC for labour indicated that the non-adopters and adopters used labour excessively, resulting in lower outputs. This implies that the rice farmers need to reduce the use of the labour input. The findings illustrate that perhaps educating rice farmers on the efficient use of inputs would greatly enhance their productivity. In general, the rice farmers are inefficient in the use of seeds, labour and herbicides. This implies that that increasing off-farm work options probably would increase farm efficiency. There is also the sufficient scope for increasing the use of these inputs in the short-run keeping the labour input constant.

Table 3. Test for structural difference using intercept and slope dummies

Variables	Coefficients	p-value
Intercept	5.82 (.58)	1.01**
Seed	.24 (.11)	.03*
Labour	-.02 (.06)	.76
Fertiliser	.08 (.02)	.01**
Herbicide	.23 (.07)	.01**
Intercept dummy	.58 (1.03)	0.58
Slope dummy for seeds	.18 (.21)	.40
Slope dummy for labour	-.20 (.07)	.18
Slope dummy for fertiliser	-.00 (.02)	.97
Slope dummy for herbicide	-.23 (.09)	.01*
No. observations	208	
R^2	.43	
F-value	16.87**	

*Note: *p < .05, **p < .01. Figures in parentheses are standard errors*

3.5 Sources of Productivity Difference between the Non-adopters and Adopters

The structural change test using the intercept and slope dummies provide the justification for decomposing the sources of the per-hectare productivity differences between the unimproved and the improved rice varieties. Accordingly, the estimated parameters of the per-hectare production functions (Table 1) and the mean input levels (Table 2) were used for the Model 7. Total changes in the productivity between the improved rice variety and the unimproved rice varieties were then decomposed into two main sources: technical change and input use differentials. The sources of the productivity differences between the improved rice variety and the unimproved rice varieties are shown in Table 5. Evidence of a moderate discrepancy exists between the observed productivity difference (44.65%) and the estimated productivity difference (39.46%) of the adopters and non-adopters. This discrepancy could be due to the random term and thus, the non-inclusion of certain factors (i.e., flood and drought), either due to quantification problem or non-availability of data.

The total estimated difference in the productivity between the improved rice variety and the unimproved rice varieties was 39.46%. Of this, technical change contributed 46.28%. This implies that with no further input application; rice productivity could be increased by 46.28% just by adopting the improved rice variety. Technical change affects output by shifting either the intercept or the slope coefficients, or both. Disaggregating technical change into neutral technical and non-neutral technical changes revealed a 0.96% contribution in the scale parameter (i.e., neutral technical change) and a 45.32% contribution from the slope parameters (i.e., non-neutral technical change). The 0.96% contribution of the neutral technical change signifies that with the present level of input used for the improved rice variety, the rice farmers could have increased the productivity level by 0.96% in rice production provided that the efficiency level of inputs use remain constant. The greatest contribution of 45.32% suggests that productivity difference between the improved rice variety and the unimproved rice varieties was mostly from the non-neutral technical change. In other words, output differences are due to the differences in resource reallocation to the various inputs used. This implies that the rice farmers were able to adjust to the requirements of the improved technology of rice production. Therefore, output differences were attributable to the shift in the slope parameter of the production function.

The results suggested that the total contribution of changes in the levels of input use to the productivity differences between the two varieties was -6.82%. This implies that the productivity of the improved rice variety could decline by 6.82% if the input use leads to increase in the same level as that of the unimproved rice varieties. The highest input contributor to the productivity differences was fertiliser, which amounted to 3.50%, followed by labour's share of 0.43. Seed and herbicide registered a negative contribution of -10.64% and -0.11%, respectively. This means that the large quantity of seeding rate applied by the non-adopters increased output by 10.64% for the unimproved rice varieties. Similarly, higher levels of herbicide application have increased the output of the unimproved rice varieties by 0.11%. Conversely, high intensities of fertiliser and labour used by the adopters had led to yield increases by 3.50% and 0.43%, respectively. This implies that the adopters gained a higher yield by spending more on fertiliser and labour than the non-adopters spend.

Generally, the results demonstrated that the total gain in productivity due to the shift from the unimproved rice varieties to the improved rice

Table 4. Resource use efficiency of the non-adopters and adopters

	Non-adopters				Adopters			
	MVP	**MFC**	**Ratio**	**Dec.**	**MVP**	**MFC**	**Ratio**	**Dec.**
Seed	6.43	2.96	2.17	UT	11.20	2.34	4.79	UT
Fertiliser	.79	.74	1.07	UT	.68	.59	1.15	UT
Herbicide	99.11	9.00	11.01	UT	8.47	6.00	1.41	UT
Labour	-.60	6.18	-.10	OT	-2.05	7.95	-.26	OT

Note: Dec.: Indicates decision. UT, ET, and OT indicate under-, efficient-, and over-utilisation of resources

variety was 46.28%, which was mainly due to non-neutral technical change, i.e., the shift in the slope coefficients. This presupposes that the productivity difference between the improved rice variety and the unimproved rice varieties was due to the re-allocation of inputs at the new level of efficiency. However, as stated earlier, the slope dummy for herbicide was the only statistically significant variable in the structural difference test (see Table 3). Hence, the major source of structural difference between the improved rice variety and the unimproved rice varieties was the non-neutral technical change, which in turn is due solely to herbicide use. The results are consistent with the finding of [16] who reported non-neutral technical change as the major source of structural difference between improved and unimproved technologies. Similarly, this study is partly consistent with [21] who established output increase as due to shift in the scale and / or slope parameters.

Table 5. Decomposition of productivity differences between adopters and non-adopters

Sources of productivity differences	**Percent contribution**
Observed differences in output	44.65
Sources of contribution	
A Due to differences in technology	
Neutral technical change	.96
Non-neutral technical change	45.32
Total due to technology	46.28
B Due to difference in input use	
Seed	-10.64
Fertiliser	3.50
Herbicide	-.11
Labour	.43
Total due to all inputs	-6.82
Estimated difference in output (A + B)	39.46

4. POLICY IMPLICATIONS

The output decomposition analysis of technological change in rice production, as done in this study, presents several policy implications in the development, dissemination and promotion of improved agricultural technologies such as improved rice variety. First, there is evidence that rice productivity could be increased through greater use of quality seeds, fertiliser, and herbicides. However, as indicated in the marginal product to marginal cost ratios in Table 4, it probably would not be efficient to increase fertiliser. The implication is that agricultural policy must seek to remove the impediments (such as access to inputs) that prevent greater use of modern inputs such as seeds and fertiliser in rice production. More specifically, input supply must (a) be decentralised to markets within the farming communities and (b) be timely and readily available in the right amount while guaranteeing their quality. In addition, farmers need to be trained on the best use of certified seeds and other improved technologies. Input requirements at the right time and in the right quantity are key to the production of improved rice varieties given the seasonality of production and recommended amounts required to achieve set output levels. More importantly, future technological options must consider the complementary nature of improved varieties and production inputs in their development.

Second, greater demands for inputs use associated with the improved rice variety pose increased burden on labour and capital-constrained rice farmers. In capital and labour-constrained, subsistence settings, resource limitation is severe and rice farmers may not adopt improved technologies. For instance, in labour surplus economies such as Ghana, the creation of employment through the development of improved agricultural technologies are best alternatives to addressing high unemployment rates, especially in rural communities. However, the resource intensive nature of the improved rice variety has grave consequences on its adoption and subsequent uptake by smallholder rice farmers because of hired labour shortage, especially during peak production periods, and limited family labour availability as well as difficulties in accessing credit. Likewise, high labour requirements limit further expansion of the cultivated land area and the potential of increasing production on rice farmers' currently cultivated land. The policy implications are that perhaps the provision of specialised credit facilities to smallholder farmers should be stepped up. Such credit facilities should be integrated into the promotional activities of resource intensive technologies such as the improved rice variety. In the same light, the government's efforts to promote rice productivity through input subsidy should be intensified and decentralised to market centres within farming communities. Moreover, the development of mechanised threshers and harvesters to substantially reduce the manual labour requirements for rice production would be a bold step to enhancing the adoption of labour intensive technologies.

Third, evidence of under-utilisation and over-utilisation of inputs in the production of rice reveals lack or inadequacy of rice farmers' technical knowledge and information required for efficient use of inputs. The practical implications are that rice sector policies must be directed at designing more intensive and integrated extension programmes that focus not only on the adoption of the improved rice varieties but also on the efficient use of recommended inputs. Finally, technology adoption can only be achieved if it has been diffused, farmers are aware of the technology and its potential gains as well as are certain about the ease of using such improved technologies within their local context. Rice sector policies must, therefore, be geared toward aggressive awareness creation and education of rice farmers on improved technologies as well as integrating the agronomic limitations of such technologies into the development of future technologies. Researchers, policy makers, and other stakeholders in the technology promotion chain could harness the knowledge gained through this analysis. Given its potential gains, the continued promotion of the improved rice variety is highly advocated as it will ensure food security, reduce the Government's overreliance on rice imports, increase farmers' income and ultimately reduce poverty among the smallholder farmers.

5. CONCLUSIONS

This study revealed the yield superiority of the improved rice variety over the unimproved rice variety. The results also indicated that the rice farmers were underutilising their resources. The estimated productivity difference between the unimproved and improved rice varieties was 39.46%. However, the major source of productivity difference was due to non-neutral technical change (45.32%). In particular, the shift in the slope coefficient of the herbicide input was the only factor responsible for the productivity difference. Neutral technical change only contributed about 1% to the productivity difference between the improved rice variety and the unimproved rice varieties. Furthermore, changes in the use of all the inputs had rather reduced the yield of the improved rice variety by 6.82%. The results of the dummy variable technique showed that the productivity difference between the improved rice variety and the unimproved rice varieties were due to non-neutral technical change (or the shift in the slope parameter) and shift in the herbicide, in particular. Hence, we rejected the hypothesis that the productivity difference between the improved and unimproved varieties were due to neutral technical change in rice production. However, we failed to reject the hypothesis that the productivity difference between the improved and unimproved varieties was due to non-neutral technical change. This means that the structural differences between two farming systems can only be determined through statistical tests and the dummy variable technique, in particular. Therefore, the dummy variable approach is a necessary and a sufficient condition for testing for the structural change and its sources between the improved rice variety and the unimproved rice varieties. Overall, the results illustrate that perhaps appropriate extension strategies and capacity building are needed to improve the resource use efficiency of the farmers to increase productivity. Also, the promotion of technology dissemination processes should be integrated with an effective input supply and credit supply systems to enable farmers' adoption and subsequent uptake of improved rice varieties for enhanced productivity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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